DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY CA 93943-5101

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

OPTIMIZING UNITED STATES MARINE CORPS ENLISTED ASSIGNMENTS

by

Brian F. Tivnan

September 1998

Thesis Advisor: Robert F. Dell
Second Reader: Hemant K. Bhargava

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	Master's Thesis

4. TITLE AND SUBTITLE
OPTIMIZING UNITED STATES MARINE CORPS ENLISTED ASSIGNMENTS

5. FUNDING NUMBERS
RBYBH

6. AUTHOR(S)
Tivnan, Brian F.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, United States Marine Corps(MA)
3280 Russell Rd., Quantico, VA 22134-5103

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

The United States Marine Corps (USMC) has 156,000 active duty enlisted Marines and annually orders over 90,000 of them to permanently change station. The Commandant of the Marine Corps requires assignments of the "Right Marine, to the right place with the right skills and quality of life." USMC manpower planning uses staffing goals (billet requirements) to capture the Commandant's requirements, but, surprisingly, does not monitor how many Marines fill appropriate staffing goal billets. This thesis finds that although the staffing goals are completely achievable, only 45% of active duty Marines fill a staffing goal billet and 47% of staffing goal billets are under-staffed. The USMC has used the Enlisted Assignment Model (EAM) since the 1970s to help enlisted monitors determine assignments. EAM has several shortcomings. Among these, enlisted monitors reject most of EAM suggested assignments and EAM offers no measure of effectiveness to gauge the quality of its assignments. This thesis presents a network model, EAM-GLOBAL to optimize the by-name assignment of Marines to staffing goal billets. EAM-GLOBAL attempts to assign the "right Marines to the right places" while simultaneously balancing staffing shortages, allowing grade and military occupational specialty substitutions, and minimizing the costs of permanent change of station transfers within the continental United States.

14. SUBJECT TERMS
Assignment Model, Staffing Goals, Manpower Models, Transportation Model, Network, Elastic Network Model

15. NUMBER OF PAGES
79

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited

OPTIMIZING UNITED STATES MARINE CORPS ENLISTED ASSIGNMENTS

Brian F. Tivnan
Captain, United States Marine Corps
B.S.M.E., University of Vermont, 1992

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1998

ABSTRACT

The United States Marine Corps (USMC) has 156,000 active duty enlisted Marines and annually orders over 90,000 of them to permanently change station. The Commandant of the Marine Corps requires assignments of the "Right Marine, to the right place with the right skills and quality of life." USMC manpower planning uses staffing goals (billet requirements) to capture the Commandant's requirements, but, surprisingly, does not monitor how many Marines fill appropriate staffing goal billets. This thesis finds that although the staffing goals are completely achievable, only 45% of active duty Marines fill a staffing goal billet and 47% of staffing goal billets are under-staffed. The USMC has used the Enlisted Assignment Model (EAM) since the 1970s to help enlisted monitors determine assignments. EAM has several shortcomings. Among these, enlisted monitors reject most of EAM suggested assignments and EAM offers no measure of effectiveness to gauge the quality of its assignments. This thesis presents a network model, EAM-GLOBAL to optimize the by-name assignment of Marines to staffing goal billets. EAM-GLOBAL attempts to assign the "right Marines to the right places" while simultaneously balancing staffing shortages, allowing grade and military occupational specialty substitutions, and minimizing the costs of permanent change of station transfers within the continental United States.

TABLE OF CONTENTS

LIST OF ACRONYMS

AFPC	Air Force Personnel Center
AMPL	A Modeling Language for Mathematical Programming
ASR	Authorized Strength Report
BMOS	Billet Military Occupational Specialty
BUPERS	Unites States Navy Bureau of Personnel
CMCC	Current Monitored Command Code
CONUS	Continental United States
DCTB	Date Current Tour Began
DSAI	Decision Systems Associates, Incorporated
EAM	Enlisted Assignment Model
EAM-GLOBAL	Enlisted Assignment Model – Global
EAS	End of Active Service
ELIM	Enlisted Inventory Loss Model
EPANS	Enlisted Personnel Allocation and Nomination System
ESGM	Enlisted Staffing Goal Model
FMCC	Former Monitored Command Code
FYDP	Future Years Defense Plan
M&RA	Manpower and Reserve Affairs
MBU	Marine-Billet Utility
MCC	Monitored Command Code
MCTFS	Marine Corps Total Forces System
MOE	Measure of Effectiveness
MOS	Military Occupational Specialty
MOSLS	Military Occupational Specialty Level System
OCD	Overseas Control Date
OCONUS	Outside Continental United States
PCA	Permanent Change of Assignment
PCS	Permanent Change of Station
PMOS	Primary Military Occupational Specialty
RTD	Rotation Date
SPL	Staffing Priority Level
T2P2	Trainees, Transients, Patients, and Prisoners
USA	United States Army
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

Thanks to INSIGHT, INC. of Manassas, VA for providing without remuneration the network solver, ENET, to this project. Thanks to Captain Edward Dewald, USMC, whose technical expertise and enthusiasm for this project proved invaluable. Further appreciation to the faculty of the Department of Operations Research, Naval Postgraduate School, not solely for their guidance in this project, but also for their respective contributions to an outstanding educational experience. A mere acknowledgment of Dr. Robert Dell's encouragement and insight does not repay the debt to him. Finally, a special thanks to my wife, whose limitless support and understanding bestowed success upon this project.

EXECUTIVE SUMMARY

The United States Marine Corps (USMC) has 156,000 active duty enlisted Marines and annually orders over 90,000 of them to permanently change station. The Commandant of the Marine Corps requires assignments of the "Right Marine, to the right place with the right skills and quality of life." USMC manpower planning uses staffing goals (billet requirements) to capture the Commandant's requirements, but, surprisingly, does not monitor how many Marines fill appropriate staffing goal billets. This thesis verifies the current inventory of active duty enlisted Marines can achieve over 99% of the staffing goals. Unfortunately, this thesis also estimates that only 45% of active duty Marines fill a staffing goal billet and that 47% of staffing goal billets are under-staffed. The USMC needs to start monitoring how well it satisfies staffing goals so it can manage better manpower.

The USMC has used the Enlisted Assignment Model (EAM) since the 1970s to help enlisted monitors determine assignments. EAM has several shortcomings; among these, the enlisted monitors reject most of its suggested assignments and EAM offers no measure of effectiveness (MOE) to gauge the quality of its assignments.

This thesis presents a network model, Enlisted Assignment Model-Global (EAM-GLOBAL), to optimize the by-name assignment of Marines to staffing goal billets. USMC policy governs allowable assignments; we partition policies into three categories: billet, Marine, and Marine-billet interaction. Billet concerns include staffing priority level (SPL), allowable substitutions, gender restrictions, and deployment status of the monitored command code. Marine concerns include the Marine's grade, military occupational specialty, and eligibility for overseas assignments. Marine-billet interaction

includes the balancing of staffing shortages and minimizing the costs of permanent change of station transfers within the continental United States.

EAM-GLOBAL contains four assignment MOEs to gauge how well its assignments satisfy USMC policy: (1) Fill percentage of billets by geographic location and SPL; (2) Number of transcontinental United States transfers; (3) Percentage of filled billets with perfect fit (exact grade and military occupational specialty match); and (4) Number of Marines available but not assigned. Prototypic assignment scenarios consist of up to 10,200 Marines, 16,100 billets, and 2.3 million candidate Marine-billet assignments. EAM-GLOBAL generates these test scenarios problems within 15 minutes and solves each within 3 minutes on a 400 megahertz Pentium II personal computer. EAM-GLOBAL attempts to assign the "right Marines to the right places" while simultaneously seeking to balance staffing shortages, allow grade and military occupational specialty substitutions, and minimize the costs of permanent change of station transfers within the continental United States.

This thesis offers two principal recommendations for USMC manpower: USMC should monitor how well it satisfies staffing goals, and it should implement an effective personnel assignment model, such as EAM-GLOBAL.

I. ASSIGNMENTS OF USMC ENLISTED MARINES

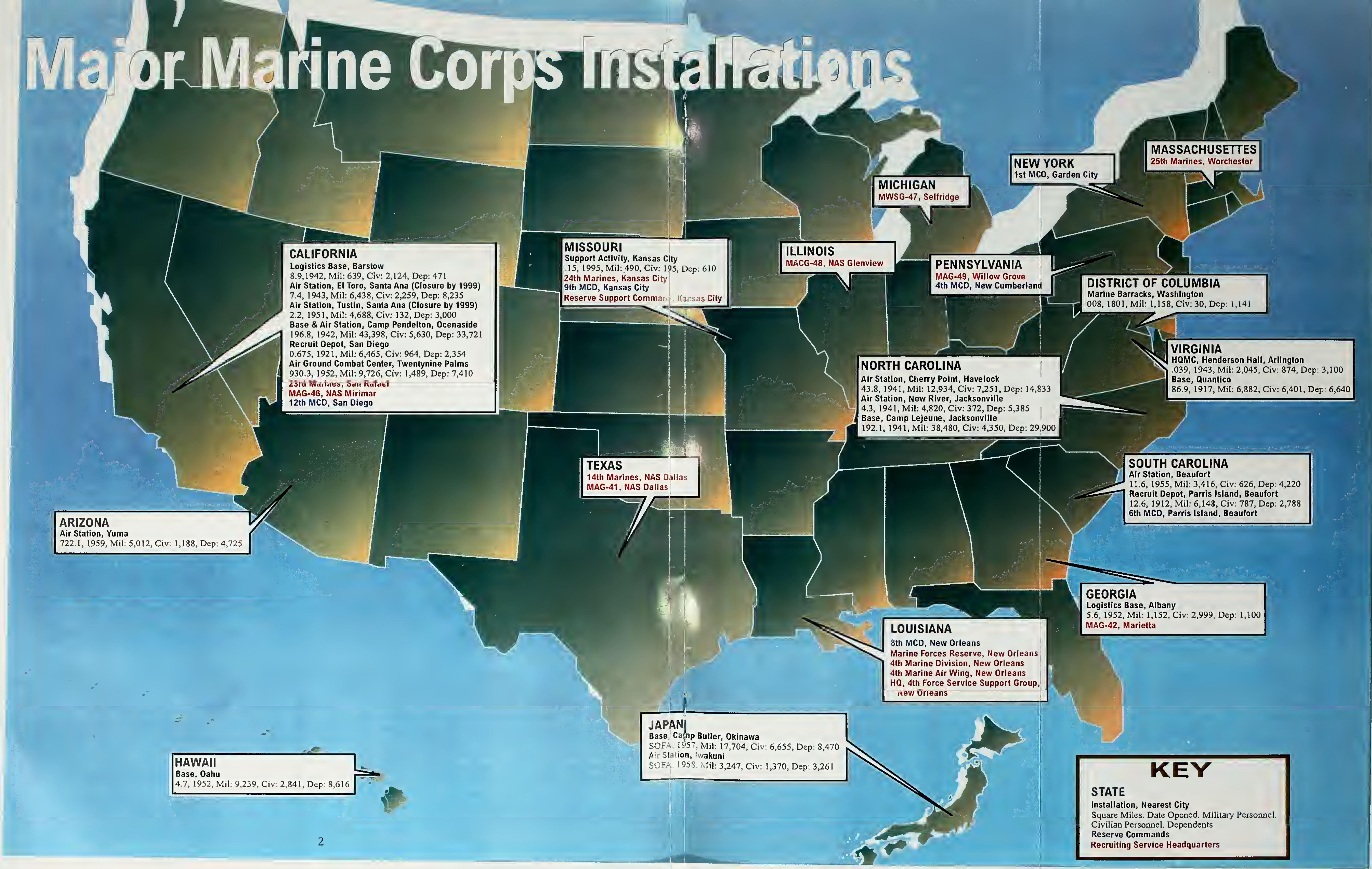
The United States Marine Corps (USMC) has 156,000 active duty enlisted Marines geographically distributed throughout the world (Figure 1.1) [*Marines* 1997]. USMC annually designates over 90,000 of these Marines for Permanent Change of Station (PCS) orders [Meckel 1998]. The Commandant of the Marine Corps requires assignments of the "Right Marine, to the right place with the right skills, and quality of life." With these right assignments, the Commandant expects to reduce attrition and thereby improve the overall effectiveness of the entire organization.

We address the problem of monthly optimizing the by-name assignments of Marines using a network model, Enlisted Assignment Model-Global (EAM-GLOBAL). EAM-GLOBAL offers the capability to assist the Manpower and Reserve Affairs (M&RA) Division of Headquarters, USMC, in assigning those "right Marines to the right places."

A. THESIS ORGANIZATION

The remainder of this chapter describes how Marines are assigned, issues associated with PCS assignments, and summary statistics of current USMC staffing levels. Chapter II reviews related Operations Research literature. Chapter III describes EAM-GLOBAL, detailing its evolution through

Major Marine Corps Installations



several stages. Chapter IV describes the EAM-GLOBAL implementation and computational results. Chapter V presents conclusions and recommendations for further endeavors.

B. CURRENT MANPOWER PLANNING

USMC manpower planning relies on several decision support tools for guidance. Separate tools exist to determine an authorized USMC manpower strength, the staffing levels of specific billets, and the assignment of individual Marines to those billets. We provide only a brief description of planning assignments of enlisted Marines; see Marine Corps Order P1300.8R, Personnel Assignment Policy [USMC 1990] for a more detailed description.

1. Authorized Strength

The Authorized Strength Report (ASR) constrains the combat-based manpower requirements by budgeted man-year and "Transients, Trainees, Patients, and Prisoners" (T2P2). T2P2 approximates Marine unavailability arising when Marines spend time as: transients (executing PCS orders), trainees (receiving training), patients (receiving medical care), and prisoners (serving a confinement sentence). The ASR classifies billets by current year, budget year, and the remaining five years of the Future Years Defense Plan (FYDP) [Deputy Chief of Staff/M&RA 1996].

The ASR identifies billets by grade, military occupational specialty (MOS), and Monitored Command Code (MCC). Grade represents the rank of the Marine required for the billet. MOS identifies the specific training and technical skills required for the billet. MCC represents the individual unit possessing the billet.

For the current year, the ASR provides the authorized billets for staffing. The list of authorized billets for outyears is used in planning to develop the right "kinds" of Marines (*i.e.*, those with needed skills) [Deputy Chief of Staff/M&RA 1996].

2. Staffing Goals

Authorized billets from the ASR represent ideal staffing goals. These goals must be reconciled with the current inventory and USMC distribution policies. The complete population of active duty enlisted Marines constitutes the current inventory. Distribution policies determine Marine allocation if shortages occur in the available inventory. The Enlisted Staffing Goal Model (ESGM) determines the distribution of the staffing goals by grade, MOS, and MCC. ESGM's staffing goals become target assignments.

3. Assignments

The final step is the generation of by-name assignments of Marines to billets.

C. ISSUES ASSOCIATED WITH POTENTIAL ASSIGNMENTS

Several issues affect the desirability of Marine-billet assignments. This thesis breaks these issues into five categories: the billet, the Marine, the interaction between Marine and billet, the fit of a Marine to a billet, and the fill.

1. Assignment Issues Associated with the Billet

A billet is defined by the following three characteristics: MCC, grade requirement, and MOS requirement. The staffing priority level (SPL), allowable grade and MOS substitutions, gender restriction, and deployment status of the billet govern candidate assignments.

a. Staffing Priority Level (SPL)

Each billet has one of three staffing priorities; from highest to lowest precedence, the SPL classifications are Excepted, Priority, and Proportionate Share.

b. Grade Substitution

The SPL of each billet determines allowable grade substitutions. Excepted SPL billets have no allowable grade

substitutions; for Priority and Proportionate Share billets, a Marine having a grade one rank above the billet requirement can be substituted (this is called a "One Down" substitution) or a Marine having a grade one rank below the billet requirement can be substituted (this is called a "One Up" substitution). Assigning a Marine with the grade of E-5 to a billet with a requirement for a Marine with a grade of E-6 is an example of a "One Up" grade substitution. M&RA prefers "One Up" over "One Down" substitutions.

c. MOS Substitution

The SPL also determines the possibility for MOS substitution. Billets with an Excepted SPL do not allow for MOS substitution. However, some billets can be filled by a Marine of any MOS. In still other cases, billet requirements permit the assignment of a Marine to a billet for which he does not possess the exact technical skills. Instead, the Marine possesses technical training from the same MOS family of technical skills. Assigning a Marine with a MOS of 0341 (infantry mortarman) to a billet requiring a Marine with a MOS of 0331 (infantry machinegunner) is an example of MOS substitution. Notice the first two digits of the four-digit MOS are the same (in this case, 03). This matching of the first two digits denotes that the two MOSs come from the same technical family (in this case, Infantry).

d. Gender Restriction

Gender restriction prohibits a female from serving in a MCC designated as a combat unit (for example, V34, which designates the infantry battalion, "Third Battalion, Fourth Marines").

e. Deployed Units

Manpower policy prohibits the assignment of Marines into or out of units during the training period preceding a deployment known as the "Lock-On" period, or during the deployment.

2. Assignment Issues Associated with Each Marine

The assignment issues associated with the Marine include the Marine's primary MOS (PMOS), billet BMOS (BMOS), current MCC (CMCC), former MCC (FMCC), sex, date current tour began (DCTB), rotation date (RTD), end of active service (EAS), and Overseas Control Date (OCD). Each row of Table 1.1 contains a sample of data from Marine Corps Total Force System (MCTFS). This system maintains all relevant Marine data except OCD.

GRD	PMOS	BMOS	CMCC	FMCC	S	DCTB	RTD	EAS
3	7222	7222	1EH	1EH	M	19950612	0	19980830
3	4066	4067	092	K76	M	19970112	19990112	20000602
3	0311	0311	V33	V13	M	19960204	0	19990723
8	2591	2591	1F6	121	M	19970128	19980126	19990223
4	0193	0193	KAA	D18	M	19950214	0	20010213

Table 1.1. Sample Data from Current Inventory of Active Duty Enlisted Marines. Source: Marine Corps Total Force, October 1997. The eight-digit date format identifies the year, the month, and the day of the month (*i.e.*, YYYYMMDD). Each row of data represents a Marine. For example, the second row represents a Marine with a grade of 3, a primary MOS of 7222, a billet MOS of 7222, a current MCC of 1EH, a former MCC of 1EH, a male, a date current tour began of 19950612, a rotation date of zero (a nonzero indicates when a Marine is eligible for a PCS transfer to return to the Continental United States), and an end of active service of 19980830.

The PMOS of the Marine represents the Marine's formal training and technical skills. The Marine's BMOS represents the skills required for the Marine's currently assigned billet. Notice that if a MOS substitution has occurred, the Marine's primary and billet MOSs do not match exactly, beyond the first two digits (See row 3 of Table 1.1). The CMCC shows the MCC of the Marine's current billet; the FMCC shows to the Marine's previous assignment. The DCTB reveals the beginning of the Marine's current tour. The RTD applies solely to Marines currently serving in billets outside the Continental United States (OCONUS). If a Marine has an OCONUS CMCC, the RTD depicts when the Marine becomes eligible for orders to return to the Continental United States (CONUS). The EAS reveals the remainder of the Marine's contractually obligated service.

A Marine currently serving in an OCONUS billet cannot be involuntarily assigned to another OCONUS billet for a period of twenty-four months. Properly using the OCD ensures compliance with this policy [Marine Corps Order P1300.8R].

3. Assignment Issues Associated with the Interaction between the Marine and the Billet

The interactions of Marine and billet assignments involve the following issues: balancing of shortages between major commands and minimizing assignments that require PCS transfers.

Keeping East and West Coast units staffed to similar fill percentages for billets in like SPLs illustrates the concept of balancing shortages between major commands.

Reducing PCS transfers saves PCS costs and enhances geographic stability for Marine families. Permanent Change of Assignment (PCA) transfers are preferable to PCS transfers. PCA transfers change the billet but do not re-locate the Marine. When PCS is unavoidable, a Mississippi River crossing is a good surrogate for high-cost CONUS PCS. Whenever possible, a transcontinental PCS transfer should be avoided.

4. Assignment Issues Associated with the Fit of a Marine to a Billet

The fit of a Marine to a billet identifies the match in grade and MOS between the Marine and the billet. A perfect fit assignment represents an exact match in grade and MOS between the Marine and the billet. An "One Up" substitution of a Marine with the same MOS as that of the billet represents a nearly perfect fit assignment.

5. Assignment Issues Associated with Fill

Fill only addresses the aggregate achievement of the Staffing Goals and, therefore, is independent of fit.

D. ANALYSIS OF CURRENT USMC STAFFING LEVELS

The following discussion provides a snapshot of the USMC staffing levels for October 1997 as reported in the MCTFS [EAM Turnover File 1997]. Although the USMC does not presently use any MOEs to monitor staffing levels, the following seem sensible:

1. Percentages of Marines assigned and not-assigned to Staffing Goal billets, and
2. Percentages of billets filled to, above, and below the Staffing Goal.

The remainder of this section reports the application of these simple MOEs to the current USMC staffing levels.

ESGM identifies 33,289 unique billets and a total demand for 126,696 Marines. The inventory includes files on 156,363 Marines. There were 1,065 instances of incomplete data limiting the available inventory of active duty Marines to 155,298. Because twenty percent of the active duty force is not available for duty at any given time, there must be a surplus of nearly 30,000 Marines (156,363 Marines for 126,696 billets). T2P2 contributes such unavailability.

1. Current Staffing of USMC

We determine the summary statistics for the current staffing level of the USMC as follows:

> For each match of the CMCC, grade, and BMOS of a Marine in the inventory with the MCC, grade, and MOS of a billet in the staffing goals, decrement the demand of that billet by one.

This does not consider grade or MOS substitution, but only exact matches between the current MCC, grade, and billet MOS of the Marine to the MCC, grade, and MOS of the billet.

Currently, only 45% of all active duty enlisted Marines fill a staffing goal billet.

Currently, 47% of all staffing goal billets are under-staffed.

11,276 of 33,289 billets are filled to their respective staffing goals, 15,814 are filled below their respective staffing goals, and 6,199 are filled above their respective

staffing goals (over-staffed). The over-staffed billets account for 16,661 Marines. **See Table 1.2 and Table 1.3. Judging by these simple, unambiguous MOEs, the current system has not met the staffing goals of the USMC.**

	Number of Marines	Percentage of Marines
Assigned to Authorized Billet	69,509	44.4
Assigned to Over-staffed Billet	16,661	10.7
Not Assigned to Authorized Billet	69,128	44.2
Incomplete Data	1,065	0.7
Total	156,363	100.0

Table 1.2. Current Marine Staffing Levels. Only 44.4% of Marines are assigned to staffing goal billets. The USMC seeks 80%.

	Number of Billets	Percentage of Billets
Filled to Staffing Goal	11,276	33.9
Filled Below Staffing Goal	15,814	47.5
Filled Above Staffing Goal	6,199	18.6
Total	33,289	100.0

Table 1.3. Current USMC Billet Staffing Levels. The current inventory should permit the fulfillment of 100% of the staffing goal billets (as indicated, they are only filled to 33.9%). By allowing over-staffing to occur, USMC produces shortages in nearly 50% of its staffing goal billets.

2. "Free" Staffing of USMC

We compare the current staffing of the USMC to a concept we call "Free" staffing. "Free" staffing considers each Marine in the current inventory as unassigned and available for assignment to any appropriate billet. We determine the summary statistics for the "Free" staffing level of the USMC as follows:

> For each match of only the grade and PMOS of a Marine in the inventory with the grade and MOS of a billet in the staffing goals, decrement the demand of that billet by one.

This does not allow for over-staffing, grade substitution, or MOS substitution, but allows only exact matches between the grade and primary MOS of the Marine to the grade and MOS of the billet.

The "Free" staffing level of the USMC is 99 % of the staffing goal, and 81 % of active duty Marines could fill a staffing goal billet (see Tables 1.4 and 1.5). These percentages validate the staffing goals as achievable based on the active duty inventory of enlisted Marines; **the USMC is simply not achieving its goals using current manpower planning (see Tables 1.2 and 1.3).**

	Number of Marines	Percentage of Marines
Assigned to Authorized Billet	126,227	80.7
Assigned to Over-Staffed Billet	0	0.0
Not Assigned to Authorized Billet	29,071	18.6
Incomplete Data	1,065	0.7
Total	156,363	100.0

Table 1.4. "FREE" Marine Staffing Levels. If all Marines are made available for assignment, 80.7% of Marines would be assigned to staffing goal billets. This is in stark contrast to the current level of 44.4% shown in Table 1.2.

	Number of Billets	Percentage of Billets
Filled to Staffing Goal	33,072	99.3
Filled Below Staffing Goal	217	0.7
Filled Above Staffing Goal	0	0
Total	33,289	100.0

Table 1.5. "Free" USMC Billet Staffing Levels. If all Marines are made available, 99.3% of the staffing goal billets would be filled to their staffing goal. This is in stark contrast to the current level of 33.9% shown in Table 1.3.

II. RELATED RESEARCH

In addition to the military services, many large-scale organizations encounter manpower planning problems. These problems commonly require determining an allocation of manpower resources that best satisfy operational requirements. The widespread application of manpower planning has encouraged much research in the field. This chapter presents a brief overview of manpower planning models and pays particular attention to the manpower planning models developed for the other U.S. military services. It concludes with a description of network models for USMC manpower planning and a presentation of the capabilities and limitations of USMC's current enlisted assignment model.

A. MANPOWER PLANNING MODELS

Gass [1991] provides an excellent overview of manpower planning models. He describes the assumptions and applications of the transition rate and network models.

1. Transition Rate Model

Gass states that traditional transition rate models forecast personnel inventory levels based on known transition rates. Gass defines this problem as, "Given a work force described by class descriptors at the beginning of the period, what is the composition of the force at the

end of the planning period." Gass refers to this model as the Markov model due to the assumption that a Markov process independently governs each individual. He states that Markov models estimate new hires, separations, retirements, training requirements, shortages by class, and steady-state inventories.

2. Network Models

Gass discusses the application of network models to address personnel assignment problems. Gass defines the personnel assignment problem as the assigning of individuals in personnel categories to jobs in job categories so as to minimize the cost of the assignments. Conservation of flow through each node in the network represents the fundamental assumption of this model. Gass' discussion of network models also demonstrates the equivalence between the personnel assignment model and the transportation network model. Gass refers the interested reader to a paper by Klingman and Phillips [1984] that discusses the USMC assignment problem.

Klingman and Phillips [1984] present the merits of modeling the USMC assignment problem as a capacitated transshipment problem. In addition to Klingman and Phillips, several authors of papers on network models reference the algorithm of Bradley *et al.* [1977] for an

efficient solution to the transshipment problem [*e.g.*, Bausch *et al.* 1991, Sweeny 1993].

B. MANPOWER MODELS IN THE OTHER U.S. MILITARY SERVICES

All of the U.S. military services have requirements for large-scale manpower decision support. However, each service uses a different approach. The following presents an overview of the approaches of the United States Army (USA), the United States Air Force (USAF), and the United States Navy (USN).

1. Manpower Decision Support in the United States Army

For enlisted manpower planning, the USA mainly uses two manpower models, the Enlisted Loss Inventory Model (ELIM) and Military Occupational Specialty Level System (MOSLS) [Lawphongpanich 1998]. ELIM assists the USA in managing the enlisted personnel strength at an aggregate level. MOSLS assists the USA in managing enlisted strength at the MOS and grade level.

Schank *et al.* [1997] provide an overview of ELIM. ELIM determines the number of annual accessions (recruits) necessary during each of the seven inventory projection years of the FYDP. ELIM employs two steps. First, ELIM forecasts the future enlisted personnel levels for each of the seven inventory projection years via simulation. Second, ELIM uses optimization to determine the monthly

accession levels necessary to minimize the deviation between the number of required billets and the number of individual soldiers available to fill them.

Schank *et al.* [1997] describe ELIM as "difficult to comprehend" and "not user friendly." Originally created in the early 1970s, ELIM's substantial modifications and two-hour runtimes hinder the ability to do "what-if" types of analyses.

Like ELIM, Schank *et al.* [1997] state that MOSLS also uses both simulation and optimization to balance the MOS and grade level requirements of the USA with available inventory. The optimization modules consider legal, budget, and resource constraints to determine the Army's optimal personnel management actions. The simulation modules predict the behavior of the inventory by replicating probable loss, aging patterns, and training graduation rates.

Schank *et al.* [1997] report that MOSLS exhibits runtimes of 22 to 24 hours. They speculate that these excessive runtimes and the expertise required to conduct the monthly runs likely will prevent the USA from ever conducting the MOSLS runs independent of the supporting civilian contractor. The contractor that originally developed the model remains the prime contractor for model upgrades, enhancements, and overall support to the USA manpower community.

2. Assignments in the United States Air Force

The USAF annually transfers 80,000 of its 299,600 airmen [Brooks 1998]. The Air Force Personnel Center (AFPC) [1993] annually allocates these transfers in four three-month cycles; each cycle alternates between an OCONUS and CONUS phase. Each OCONUS allocation replaces projected overseas losses based on airmen's eligibility dates for return to CONUS. Each CONUS allocation provides replacements for projected CONUS losses.

Brooks [1998] describes an allocation cycle in the following six steps:

1. AFPC determines personnel requirements through data processing;
2. Assignment personnel at each USAF major command review and possibly revise these requirements;
3. AFPC advertises the authorized requirements on the Internet;
4. Eligible airmen submit requests for voluntary assignment to one of the authorized requirements;
5. AFPC matches airmen to requirements to include matching airmen to involuntary assignments; and
6. Commander of the AFPC authorizes the assignments.

3. Assignments in the United States Navy

Although the USN has never used optimization for making its assignments, the Navy problem has been well studied. Ali *et al.* [1993] present the Enlisted Personnel Allocation and Nomination System (EPANS). EPANS optimizes the USN's more than 200,000 annual enlisted transfers which result in over $250 Million in moving expenses. EPANS also addresses the problem of enlisted assignments with en route training. That is, an individual becomes eligible for additional billets if that individual can attend a technical school while en route to a new assignment. Ali *et al.* present an algorithm to solve an integer network problem based on resource-directive decomposition in conjunction with Lagrangian relaxation. Ali *et al.* report runtimes of 32 seconds on an IBM 9370 on their largest test problem of 169 sailors, 109 billets, 35 schools, and 3,633 arcs.

Cunningham [1998] states that EPANS encountered "institutional resistance and a lack of interest" resulting in the United States Navy Bureau of Personnel (BUPERS) not implementing EPANS. Cunningham states that the USN, instead, makes assignments "first come, first served." Cunningham admits "the process is not efficient but the USN has done it this way for thirty years." Cunningham adds that the USN would "like to progress to an optimization approach."

C. NETWORK MODELS FOR THE USMC

Three papers present network models for USMC manpower planning problems. Bausch *et al.* [1991] discuss a network model for optimizing the assignments of USMC officers for a wartime mobilization. Sweeny [1993] develops and implements a network linear programming model to assist in the peacetime allocation of USMC officers to meet manpower requirements. Snoap [1998] presents a network linear program to assist in the assignment of Marine recruits to technical schools upon their completion of recruit training.

1. USMC Officer Mobilization

Bausch *et al.* [1991] address the USMC officer mobilization problem with an optimization model, Officer Mobilization Model, that combines three objectives: maximize fill, maximize fit, and minimize turbulence by maintaining unit integrity. They introduce a network model in which a unique node represents each officer and each unique billet. A typical instance of this problem contains 40,000 officers and 25,000 billets resulting in as many as 1,000,000,000 possible officer-billet assignments. To reduce the size of the network, Bausch *et al.* reduce the model by node aggregation, arc screening, and an elastic network solver. Node aggregation combines officers with like grade, gender, MOS, and MCC into a single officer-supply node. Similarly, billets with matching data merge to create a billet-demand

node. Arc screening removes from the network any possible officer-billet assignments that do not meet USMC manpower policy. The elastic network solver (ENET, [INSIGHT 1991]) handles explicit arcs representing unused officers and unfilled billets and handles these arcs implicitly. By reducing the size of the network, Bausch *et al.* reduced the network generation and optimization times for their model from 30 minutes to 3.5 minutes on an IBM 3033-AP mainframe [Bausch *et al.* 1991].

2. USMC Officer Staffing Goal

Sweeny [1993] solves the USMC officer staffing goal problem with a network linear programming model, Officer Staffing Goal Model. Sweeny transforms his model from a simple transportation model that maximizes fit into a network model with priority classes and proportionate sharing that still maintains the best fit subject to the maximum fill. Sweeny formulates his model as an elastic network and also uses ENET for a solver [Sweeny 1993].

3. USMC Recruit Distribution

Snoap [1998] addresses the problem of assigning USMC recruits to technical schools upon their completion of recruit training. Snoap [1998] describes the development of the Recruit Distribution Decision Support System, an assignment model formulated in A Modeling Language for

Mathematical Programming (AMPL) [Fourer *et al.* 1993]. RDdss minimizes the number of empty school quotas while maximizing the fit of each Marine-school assignment.

D. ENLISTED ASSIGNMENT MODEL

The current USMC decision support tool for assigning Marines to billets is the Enlisted Assignment Model (EAM). A private contractor, Decision Systems Associates, Inc. (DSAI), owns the proprietary EAM code [Evers 1998]. This thesis provides only a brief description of EAM; see Koch [1998] for more details.

The USMC pays DSAI for the use of its proprietary code, model maintenance, and technical support of EAM [Evers 1998]. EAM runs monthly and identifies Marines for orders and assigns Marines for PCS orders to be executed six months into the future. EAM, originally designed in the late 1970s and written in FORTRAN-77, is a "rule-based", sequential heuristic [Koch 1998]. The model consists of some 16,000 user-defined logical expressions. These logical expressions make the model extremely flexible but difficult to manage [Macfarlane 1997].

1. Current Acceptance of Assignments

Senior staff non-commissioned officers serve as monitors within their respective MOSs. It is the mission of these monitors to oversee the assignments of Marines within

their MOS for PCS orders. The monitors express satisfaction with EAM's pre-processing of the input data [Manes 1997]. However, in most cases, monitors do not concur with the assignments being generated by EAM [Macfarlane 1997]. The monitors predominantly use the output from EAM to identify Marines that are available for re-assignment [Marren 1997]. Monitors produce the assignments manually for these Marines by sorting through several data fields (manually performing a task EAM is intended to automate).

2. Limitations

EAM suffers from several limitations: Monitors do not concur with the assignments being generated by EAM; EAM does not address the assignment problem in its entirety; and EAM displays no MOE to evaluate its results.

EAM partitions the problem into disjoint subsets by MOS family and then solves a reduced assignment problem for each of these MOS family subsets [EAM Turnover Folder 1997]. This partitioning excludes certain candidate assignments.

EAM does not gauge its performance against any MOE. Therefore, there is no metric of any kind to compare successive runs or easily interpret what-if scenarios.

3. Typical Problem Instance

A representative USMC problem instance would consist of 7,500 Marines to fill 5,000 unique billets [*e.g.*, Klingman

and Phillips 1984]. These Marines and billets could possibly couple for more than 37 million Marine-billet combinations. This problem is too large for manual assignments to maintain global perspective, so a tool like EAM is essential.

Thus, if individual MOS monitors reject EAM advice and manually assign, they can hardly be cognizant of their respective technical communities and be aware of the global effects of their manual assignments on the overall achievement of USMC goals.

III. EAM-GLOBAL FORMULATION

This chapter presents the mathematical formulation of EAM-GLOBAL. The formulation evolves via a sequence of three increasingly complex models. The formulation begins with the basic transportation model, transforms this to an elastic network, and finally extends the model to an elastic network with balanced shortages.

A. OBJECTIVE FUNCTION COST COEFFICIENT

An objective function cost coefficient gauges the relative desirability of each candidate Marine-billet assignment; we call this desirability a Marine-billet utility (MBU). The monthly military pay scale (Table 3.1) provides a basis for MBU. MBU values heuristically induce desired assignment tradeoffs in EAM-GLOBAL by evaluating whether the "right Marine" would go to "the right place."

Table 3.2 provides proposed MBU values. Perfect fit assignments represent a match in grade and MOS between the Marine and the billet. ΔPay_M represents the difference in monthly pay between the grade of the Marine and that of one grade senior. ΔPay_B represents the difference in monthly pay between the grade required for the billet and that of one grade senior.

Grade	Years of Service	Monthly Pay ($)
E-1	<2	926
E-2	<2	1,038
E-3	2	1,138
E-4	3	1,280
E-5	4	1,462
E-6	8	1,780
E-7	14	2,236
E-8	18	2,648
E-9	24	3,385

Table 3.1. Monthly Basic Pay. Source: Defense Financing and Accounting Service [1998]. Years of service approximates the average years of service for a typical Marine of the corresponding grade. We use the monthly basic pay as a basis for the desirability of each candidate Marine-billet assignment.

B. BASIC TRANSPORTATION MODEL

A basic transportation model minimizes the cost of transporting a supply of a single commodity to meet demand. A transportation model forms a network that is *complete, balanced,* and *bipartite*. A complete network contains an arc connecting each supply node to each demand node [Bazaraa *et al.* 1990, p. 422]. Each supply node of the transportation model represents an individual Marine and each demand node

Assignment Issue	Addition to MBU Values
Staffing Priority Levels	
1. Excepted	-7500
2. Priority	-5000
3. Proportionate Share	-2500
Marine-Billet Geographic Interaction	
1. Marine OCONUS / Billet CONUS	$0 * \Delta Pay_M$
2. Billet OCONUS / Marine CONUS	$0 * \Delta Pay_M$
3. PCA Transfer	$1 * \Delta Pay_M$
4. PCS Transfer	$2 * \Delta Pay_M$
5. Transcontinental CONUS Transfer	$3 * \Delta Pay_M$
Grade Substitution	
1. Marine grade = Billet grade	$0 * \Delta Pay_M$
2. Marine junior to Billet (One Up)	$1 * \Delta Pay_M$
3. Marine senior to Billet (One Down)	$2 * \Delta Pay_M$
MOS Substitution	
1. Marine PMOS = BMOS	$0 * \Delta Pay_M$
2. Marine PMOS in same family as BMOS	$1 * \Delta Pay_M$
Balance of Shortages	
1. Major Command A and Major Command B staffed equally	$0 * \Delta Pay_B$
2. Assigned to Major Command A if A staffed higher than B	$1 * \Delta Pay_B$

Table 3.2. Proposed Marine-Billet Utility Values. MBU values heuristically induce desired assignment tradeoffs in EAM-GLOBAL and convey whether "right Marine" would go to "right place." ΔPay_M represents the difference in monthly pay between the grade of the Marine and that of one grade senior. ΔPay_B represents the difference in monthly pay between the grade required for the billet and that of one grade senior.

represents a billet requiring one or more Marines. A balanced network contains available supply equal to required demand [Bazaraa *et al.* 1990, p. 478]. A bipartite network consists of only supply or demand nodes - no transshipment nodes [Ahuja *et al.* 1993, p. 31]. The constraint matrix of the basic transportation model forms a *totally unimodular matrix*. With integer supply and demand data, the unimodular

matrix ensures an integer solution to a linear program [Ahuja *et al.* 1993, p.448].

EAM-GLOBAL builds on the transportation model formulation that follows.

Indices

i	Individual Marines available for Permanent Change of Station (PCS) orders (e.g., Smith, Jones, Bolton,…); and
j	Billets with a future manpower requirement (e.g., professional schools, tactical units, staffs,…).

Data (Units)

$Cost_{i,j}$	Cost of assigning Marine i to billet j (Marine-Billet Utility); and
$Openings_j$	Number of assignments required at billet j (Marines).

Decision Variable

$X_{i,j}$	One when Marine i is assigned to billet j, zero otherwise.

Formulation

$$\min_{X} \sum_i \sum_j Cost_{i,j} X_{i,j}$$

Subject To:

$$\sum_j X_{i,j} = 1 \quad \forall i . \qquad (1)$$

$$\sum_i X_{i,j} = Openings_j \quad \forall j . \qquad (2)$$

$$X_{ij} \in \{0,1\} \quad \forall i,j . \qquad (3)$$

Constraint (1) assigns each available Marine to one billet.

Constraint (2) assigns the required number of Marines to each billet. The balanced network contains available supply equal to required demand.

Constraint (3) represents assignments as binary.

For clarity, and without loss of generality, this model assumes any billet can be filled by any Marine at some cost.

C. ELASTIC NETWORK MODEL

EAM-GLOBAL extends from the basic transportation model as follows. An arc no longer connects each supply node to each demand node, and thus the network is no longer complete. This *eligibility network* only has arcs connecting supply nodes to demand nodes that represent allowable Marine-billet assignments. Due to limitations of available Marines and their eligibility to meet the demand of the required billets, the resulting model no longer has an available supply necessarily equal to or even sufficient for the required demand; notional or dummy supply and demand manage this inequity. Dummy supply meets the demand of any billet not filled by a Marine. Dummy demand absorbs Marine supply that is otherwise not eligible for any unmet demand.

Figure 3.1 illustrates a simple example constructed to indicate the features of an elastic network. Each red node offers a supply of one Marine. Each gold node represents a unique billet. For simplicity in this example, the gold billet nodes each have a demand of one Marine, but EAM-GLOBAL does not require this. The absence of an arc from Marine(i+1) to Billet(j) signifies that Marine(i+1) is not eligible to fill Billet(j). The blue node represents a

dummy supply of one Marine and accommodates the inequity between the number of available Marines and required billets; this node is implicit in EAM-GLOBAL but included here for clarity. Based on the unmet demand and the assignment eligibility of the Marines, this example does not require the green node representing dummy demand but includes it for discussion purposes.

Each arc has a capacity and a cost associated with its allowable assignment. This example includes arcs emanating from the dummy supply node to each demand node and arcs emanating from each supply node to the dummy demand node (these nodes and arcs are implicit in EAM-GLOBAL). EAM-GLOBAL uses a capacity of one for any arc emanating from a Marine supply node thus signifying no aggregation of Marines. In this example, arcs flowing from the dummy supply node or into the dummy demand node have a capacity of one. Any arc flowing from or into a dummy node has an associated cost greater than the cost of arcs flowing from Marine nodes to billet nodes.

More than one feasible solution exists for this example. EAM-GLOBAL may assign Marine(i) to Billet(j) and Marine(i+1) to either Billet(j+1) or Billet(j+2). EAM-GLOBAL will assign the dummy supply to the billet not filled by either Marine. Given assignment costs, an optimal feasible assignment can be found.

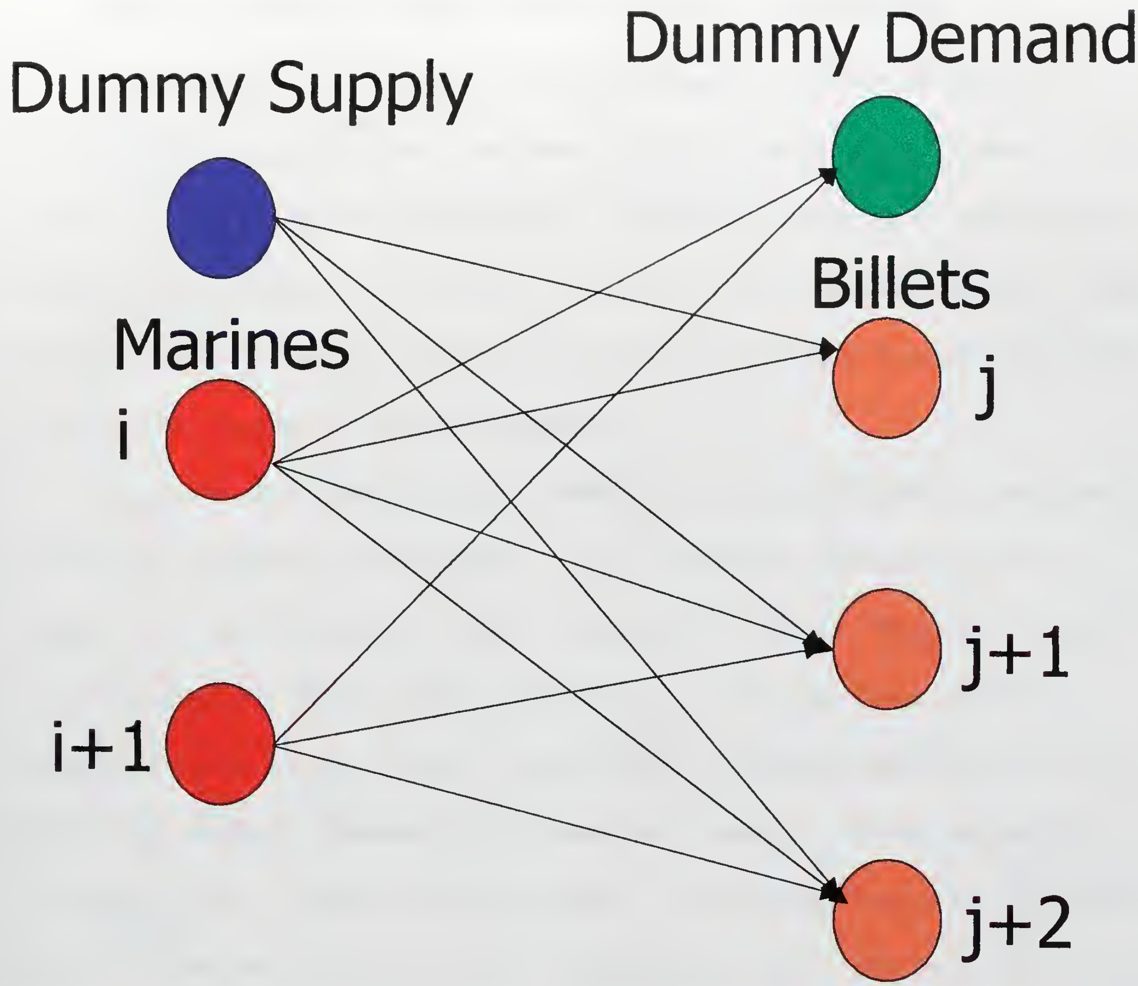


Figure 3.1: Elastic Network. Each red node represents a supply node of one Marine. Each gold node represents a demand node of one unique billet. The blue node represents dummy supply. The green node represents dummy demand. The figure contains only the incident arcs representing candidate assignments. Each arc possesses a capacity of one and an associated cost for the candidate assignment. The assignment mix that minimizes the total cost across the network represents a potential solution.

D. ELASTIC NETWORK MODEL WITH BALANCED SHORTAGES

EAM-GLOBAL extends from an elastic network model to also balance shortages between major commands. Dummy supply nodes identified by geographic location and SPL accommodate supply shortages. The cost of the arcs flowing from a dummy supply node to a billet node penalizes unbalanced staffing shortages between major commands.

Figure 3.2 depicts an example of EAM-GLOBAL designed to balance staffing shortages. The example consists of a supply of two Marines and a demand for four billets. For this example, assume that the arcs flowing from Marine supply nodes have a zero cost. The figure represents two distinct major commands as East and West. This example contains four dummy supply nodes, two each for the East and West. Assume that all arcs emanating from either blue node have the same positive cost and a supply of one, and similarly that all arcs emanating from either purple node have the same very high penalty cost. The solution to this simple example minimizes the composite sum of the cost plus penalizes for unbalanced staffing shortages between the major commands. The solution assigns Marine(i) to Billet(j+1), Marine(i+1) to Billet(j+3), and fills Billet(j+2) and Billet(j) with supply from the blue nodes. This solution provides each major command with an individual Marine.

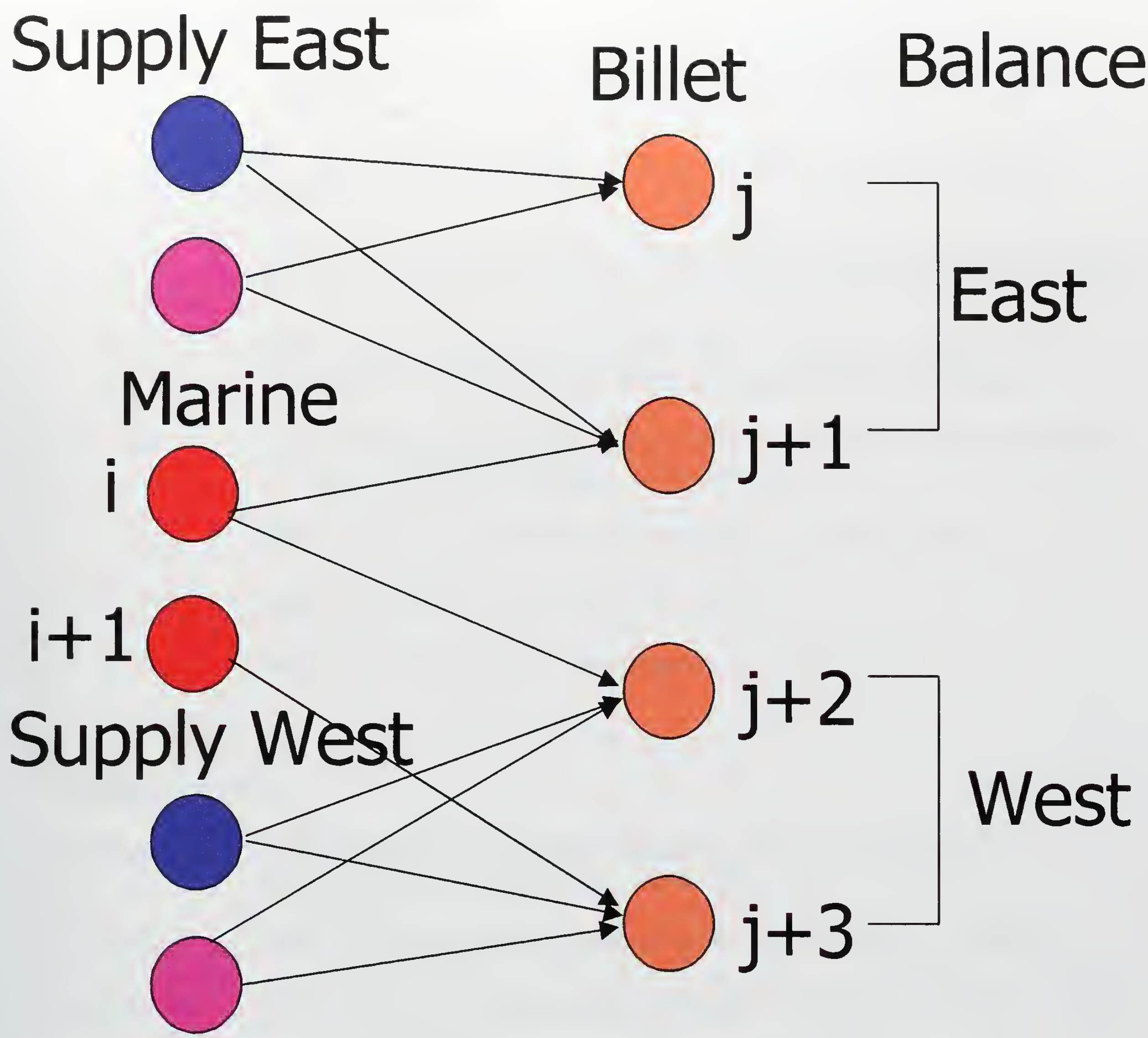


Figure 3.2: Elastic Network With Balanced Shortages. This example consists of two Marines and four billets, two in each of the two major commands. Assume that the arcs representing allowable assignments carry a zero cost, that the arcs flowing from either blue node carry the same positive cost and a supply of one, and that the arcs flowing from the purple nodes carry the same high penalty cost. The solution to this example assigns Marine(i) to Billet(j+1), Marine(i+1) to Billet(j+3), and fills the remaining two billets with supply from each of the two blue nodes. Therefore, EAM-GLOBAL assigns each command an individual Marine.

The formulation of EAM-GLOBAL with balanced shortages follows.

Indices and Index Maps

g	Geographic region of a billet (*e.g.*, East and West);
j	Unique requirements (*e.g.*, Billets and Dummy demand);
l	Discrete fill level of a billet with actual supply (*e.g.*, 80% fill, 65% fill, and 55% fill);
s	Staffing priority level of a billet (*e.g.*, Excepted, Priority, and Proportionate Share);
m	Individual Marines available for new assignments (*e.g.*, Smith, Jones, Bolton,…);
$A_{g,s}$	Set of all billets in region g with SPL s;
P_j	Maps billet j to SPL P_j; and
R_j	Maps billet j to geographic region R_j.

Data (Units)

$Bound_{l,g,s}$	Limitation on dummy supply by fill level l, geographic region g, and SPL s;
$Cost_{m,j}$	Cost of assigning Marine m to billet j (MBU);
$Futile_m$	Cost for not assigning Marine m to a billet (MBU);
$Openings_j$	Number of assignments required at billet j (Marines); and
$Penalty_{l,g,s}$	Penalty for using dummy supply from level l in geographic region g of SPL s (MCU).

Decision Variables

$Marines_{m,j}$	One when Marine m is assigned to billet j, zero otherwise;
$Unassign_m$	One when Marine m is not assigned to an actual billet, zero otherwise; and

Elastic$_{l,g,j,s}$ Represents demand at billet *j* of SPL *s* being satisfied in geographic region *g* with dummy supply from level *l*.

Formulation

$$\min_{\substack{Marine, Elastic,\\ Unassign}} \sum_m \sum_j Cost_{m,j} Marines_{m,j} + \sum_m Futile_m Unassign_m + \sum_l \sum_g \sum_j \sum_s Penalty_{l,g,s} Elastic_{l,g,j,s}$$

Subject To:

$$\sum_j Marines_{m,j} + Unassign_m = 1 \quad \forall m . \qquad (1)$$

$$\sum_{j \in A_{g,s}} Elastic_{l,g,j,s} \leq Bound_{l,g,s} \quad \forall l,g,s . \qquad (2)$$

$$\sum_m Marines_{m,j} + \sum_l Elastic_{l,"R_j",j,"P_j"} = Openings_j \quad \forall j . \qquad (3)$$

$$Marines_{m,j} \in \{0,1\} \quad \forall m,j . \qquad (4)$$

$$Unassign_m \in \{0,1\} \quad \forall m . \qquad (5)$$

$$Elastic_{l,g,j,s} \geq 0 \quad \forall l,g,j,s . \qquad (6)$$

Constraint (1) assigns each available Marine to a billet or an unassigned status.

Constraint (2) restricts the dummy supply for a given level, geographic region, and SPL.

Constraint (3) balances both actual and dummy supply with demand.

Constraints (4) and (5) stipulate that Marines and Unassign are binary variables.

Constraint (6) stipulate that Elastic is a non-negative variable.

IV. IMPLEMENTATION AND RESULTS

The chapter describes EAM-GLOBAL input files, model generation, solution, and computational results.

A. OVERVIEW

1. Problem Instances

Four different instances of the USMC assignment problem are used. M12 contains all Marines becoming available within twelve months of the draw date of the inventory data, and consists of 10,202 Marines and 16,128 billets. M09 contains all Marines becoming available for assignment within nine months of the draw date of the inventory date, and consists of 6,973 Marines and 15,712 billets. M06 contains all Marines becoming available within six months of the draw date of the inventory data (a typical problem instance for EAM), and consists of 3,424 Marines and 15,250 billets. MXM represents an instance of partitioning the solution space into disjoint MOS subsets (thus, not allowing MOS substitution), while still balancing shortages between major commands. MXM consists of the same 3,424 Marines and 15,250 billets as M06.

2. Test Computers

An IBM RS/6000 Model 595H with 1.0 Gigabyte of random access memory and an IBM-compatible 400 Megahertz personal

computer with 16 Megabytes of random access memory serve as proof prototypic test computers for the implementation of EAM-GLOBAL.

B. INPUT FILES

EAM-GLOBAL receives its data from four input files: Available Marines, Available Billets, MBU Values, and MCC Data. Details of the composition of these files follow.

1. Available Marines

The Available Marines input file originates from the MCTFS. Data processing on the entire active duty inventory produces two data files: Marines available for possible assignments and all remaining Marines. Marines serving in OCONUS assignments become available for CONUS assignments as soon as they reach their RTDs. Marines require at least 12 months of service remaining on their current contracts to transfer from CONUS to OCONUS assignments and 24 or more months to transfer from CONUS to CONUS assignments. Marines serving in CONUS billets for at least 36 months become available for CONUS and OCONUS assignments. Marines serving in CONUS billets for at least 24 but less than 36 months become available for OCONUS assignments if they do not possess a valid OCD. Table 4.1 includes availability information (*AVAIL*) on the same Marines from Table 1.1.

GRD	PMOS	BMOS	CMCC	FMCC	S	DCTB	RTD	EAS	AVAIL
3	7222	7222	1EH	1EH	M	19950612	0	19980830	**0**
3	4066	4067	092	K76	M	19970112	19990112	20000602	**0**
3	0311	0311	V33	V13	M	19960204	0	19990723	**1**
8	2591	2591	1F6	121	M	19970128	19980126	19990223	**2**
4	0193	0193	KAA	D18	M	19950414	0	20010413	**3**

Table 4.1. Available Marines. Recall that this data originates from October 1997 and that each row of data represents a Marine. An *AVAIL* value of "0" corresponds to a Marine not being available for any assignments, "1" corresponds to an availability for OCONUS assignments, "2" corresponds to an availability for CONUS assignments, and "3" corresponds to an availability for both CONUS and OCONUS assignments. For this example, Marines would execute the recommended transfers six months from the October 1997 date and, therefore, must meet time on station requirements by April 1998. The Marine in the second row does not have the minimum of 12 months before his EAS. The Marine in the third row has not met his RTD. The Marine in the fourth row has more than 12 twelve months until his EAS. The Marine in the fifth row has met his RTD. The Marine in the sixth row has 36 months in his current assignment and 36 months remaining on his EAS.

2. Available Billets

The Available Billets input file originates from the output of ESGM. Recall that ESGM identifies all required billets and the demand at each billet. Subtracting the demand met by Marines not available for assignments from the overall demand produces an account of unmet demand for each required billet. SPL data was expected to be made available for this thesis, but has not materialized at this writing. We, therefore, assume a random distribution of SPLs with 10% of all billets depicted as "Excepted", 25% as "Priority", and the remaining 65% of all billets as "Proportionate Share." Table 4.2 provides a sample from the Available Billets input file.

MCC	GRD	MOS	SPL	DEMAND
008	5	9919	O	1
008	8	9919	E	1
009	3	0121	P	4
009	2	0131	O	3

Table 4.2. Available Billets. Each row represents a unique billet. SPL identifies the staffing priority level of the billet: "E" corresponds to Excepted (highest priority) billets, "P" to Priority (average priority) billets, and "O" to Proportionate Share (lowest priority) billets. The first row represents a Proportionate Share billet at MCC 008 for one Marine with a grade of 5 and a MOS of 9919.

3. Marine-Billet Utility (MBU) Values

The Marine-Billet Utility Values input file contains MBU values for each candidate Marine-billet assignment. Recall the discussion in Chapter 3 of the determination of MBU values and the eligibility network. Table 4.3 contains the distribution of the MBU values determined using the proposed tradeoffs from Table 3.2.

This file would be re-generated with varying MBU values to investigate "what-if" scenarios.

Range ($)	Distribution of MBU Values for Each Instance of EAM-GLOBAL (%) M12	M09	M06	MXM
0 to -499	0.36	0.47	0.85	0.46
- 500 to -999	0.66	0.75	1.28	0.51
-1000 to -1499	3.40	3.40	3.62	1.26
-1500 to -1999	8.90	9.81	12.94	7.99
-2000 to -2499	49.44	48.49	44.74	38.01
-2500 to -2999	7.06	6.93	6.45	21.17
-3000 to -3499	0.27	0.30	0.51	0.22
-3500 to -3999	1.28	1.29	1.39	0.50
-4000 to -4499	3.54	3.88	5.08	3.08
-4500 to -4999	18.49	18.13	16.79	14.39
-5000 to -5499	2.67	2.63	2.39	8.19
-5500 to -5999	0.01	0.01	0.02	0.00
-6000 to -6499	0.05	0.06	0.11	0.06
-6500 to -6999	0.17	0.21	0.39	0.25
-7000 to -7499	2.59	2.56	2.46	0.56
-7500	1.11	1.08	0.98	3.35
Total Number of Arcs	2,361,565	1,652,848	812,376	226,133

Table 4.3. Distribution of Marine-Billet Utility Values for Each Instance of EAM-GLOBAL.

4. Monitored Command Code (MCC) Data

Table 4.4 provides a sample of the MCC data input file. *Location* represents the geographic location of the MCC: east of the Mississippi River is "E", west of the Mississippi River is "W", and OCONUS is "O". A match of the three-digit zip code (designated by *PCA* in Table 4.4) of a billet's MCC to the three-digit zip code of a Marine's CMCC is considered a PCA transfer. *Combat* conveys the binary representation of

the combat status of the MCC. *Deployed* conveys the binary representation of the deployment status of the MCC. Deployment data was expected, but did not arrive in time for this thesis, and is nonetheless included for discussion purposes only. At this writing, we just assume that no MCC is deployed.

MCC	PCA	Location	Combat	Deployed
063	317	E	0	0
E95	317	E	0	0
V27	922	W	1	0
V33	968	O	1	0

Table 4.4. Monitored Command Code Data. Each row of the table identifies a unique MCC. The MCC in the second row has a three-digit zip code of 317 (designated by *PCA*) and is located east of the Mississippi River. This billet is neither strictly combat nor currently deployed.

C. MODEL GENERATION AND SOLUTION

EAM-GLOBAL generates in C and solves using the elastic network program, ENET [INSIGHT 1998].

The prototypic generator is an ad hoc C program to read and edit ASCII text files (Available Marines, Available Billets, and MBU Values), to perform preemptive editing for erroneous data fields, and to generate an assignment optimization instance. Bausch *et al.* [1991] produce a much more sophisticated graphical user interface and database to perform essentially the same function. We conjecture that if USMC were to adopt any contemporary off-the-shelf

database package (*e.g.*, ORACLE [Oracle Corporation 1997] and ACCESS [Microsoft Corporation 1996]) for their complete manpower database, queries such as those in this prototypic generation would be much quicker and easier.

D. COMPUTATIONAL RESULTS

The implementations of EAM-GLOBAL demonstrate consistent runtimes. The M12 instance of EAM-GLOBAL generates within 15 minutes and solves within 15 minutes on the RS 6000 and within 3 minutes on the 400-Megahertz personal computer.

The computational results of EAM-GLOBAL are evaluated here with four assignment MOEs. We suggest these assignment MOEs to compliment the two staffing level MOEs proposed earlier. The four assignment MOEs that gauge how well assignments satisfy USMC policy are:

(1) Fill percentage of billets by geographic location and SPL;

(2) Number of transcontinental transfers within CONUS;

(3) Percentage of filled billets with perfect and nearly perfect fit (an "One Up" assignment of a Marine with the same MOS as that of the billet represents a nearly perfect fit, and an assignment of a Marine with the same grade and MOS as the billet represents a perfect fit); and

(4) Number of available Marines that are not assigned by EAM-GLOBAL.

Table 4.5 gives the size of each instance of EAM-GLOBAL. Recall that the M06 and MXM instances receive the same input data, but that M06 allows for MOS substitution, and MXM does not. MOS substitution in M06 accounts for the increase in the total number of arcs over MXM.

Table 4.5 reflects small size differences between the instances. Low, current staffing levels explain the small differences in the number of available billets between the instances. That is, only approximately 45% of all Marines currently fill authorized staffing billets; therefore, only about 45% of Marines becoming available for assignments actually vacate staffing goal billets.

In Table 4.5, *Unavailable Marines Not Assigned to Authorized Billets* identifies the number of Marines that are both not available (0 in the *AVAIL* column of Table 4.1) and not assigned to authorized billets. EAM-GLOBAL does not violate the availability criteria in order to assign these Marines to authorized billets. Hence, each instance of EAM-GLOBAL contains a limited supply for an extensive demand.

Table 4.6 displays computational results for the four instances.

EAM-GLOBAL balances its assignments between East and West CONUS commands for each instance to provide nearly equal fill percentages. For example, the M12 fill of 43.8%

(596 Marines for a demand of 1,362) for East Coast Excepted SPL billets is almost identical to the West Coast fill of 42.8% (586 Marines for a demand of 1,369)

EAM-GLOBAL also requires few transcontinental PCS transfers within CONUS for each instance.

With, on average, at least four available billets for each available Marine (*e.g.*, M12: demand of 41,373 for 10,202 Marines), EAM-GLOBAL mostly suggests Perfect and Nearly Perfect Fit assignments. For M12, EAM-GLOBAL suggests 82.1% Perfect Fit assignments (8,265 of the 10,201 assignments) and 10.2% Nearly Perfect Fit assignments (1,027 of the 10,201 assignments).

The modeled Marine-Billet Utility values produce several "One Up" assignments (represented by *Nearly* in Table 4.6) and few "One Down" assignments. EAM-GLOBAL assigned almost every available Marine.

	Size of Each Instance of EAM-GLOBAL			
Characteristic	**M12**	**M09**	**M06**	**MXM**
Available Marines	10,202	6,973	3,424	3,424
Available Billets	16,128	15,712	15,250	15,250
Total Demand	41,373	39,012	36,693	36,693
Total Number of Arcs	2,361,565	1,652,848	812,376	226,133
Unavailable Marines Not Assigned to Authorized Billets	49,367	49,928	50,561	50,561

Table 4.5. Size of Each Instance of EAM-GLOBAL. M06 and MXM instances receive the same input data: M06 allows for MOS substitution, MXM does not. *Unavailable Marines Not Assigned to Authorized Billets* represents the number of Marines not available for assignment and currently not assigned to meet a staffing goal.

Comparison of the M06 and MXM instances illustrates several key points. M06 increases fill percentages over MXM for Excepted billets (the highest priority billets) from 10.1 to 12.0 for East Coast billets and from 10.0 to 14.5 for West Coast billets. The number of unassigned, available Marines is reduced from thirty-one for MXM to one for M06. The benefits of M06 over MXM "cost" an additional 17 PCS moves and decrease fill of Priority billets from 16.6% to 15.8% in the West and from 17.3% to 16.2% in the East.

Instances	Filled Billets (%)		CONUS PCS Moves	Fit Billets (%)	Marines Not Assigned
	East	West			
M12	SPL: Excepted 43.8 Priority 50.0 Share 25.4	 42.8 56.5 30.1	0	Perfect 82.1 Nearly 10.2	1
M09	SPL: Excepted 27.5 Priority 37.1 Share 15.7	 31.8 46.7 18.5	0	Perfect 88.9 Nearly 6.5	1
M06	SPL: Excepted 12.0 Priority 15.8 Share 10.0	 14.5 16.2 10.0	27	Perfect 92.9 Nearly 3.8	1
MXM	SPL: Excepted 10.1 Priority 16.6 Share 10.0	 10.0 17.3 10.0	10	Perfect 95.1 Nearly 4.6	31

Table 4.6. Computational Results of EAM-GLOBAL. The computational results include results for the four instances of EAM-GLOBAL: M06 (3,424 Marines, 15,250 billets), M09 (6,973 Marines, 15,710 billets), M12 (10,202 Marines, 16,128 billets), and MXM (MOS by MOS with 3,424 Marines, 15,250 billets). Recall the Staffing Priority Levels (SPLs) consist of Excepted, Priority, and Proportionate Share. For Fit Billets, *Perfect* represents assignments with matching grade and MOS, *Near* represents assignments with matching MOS and 1-Up grade relationship. Recall that 1-Up identifies assignments with the Marine one rank junior to the billet requirement.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The current inventory of active duty enlisted Marines allows for the achievement of over 99% of the current staffing goals. But, this thesis estimates only 45% of all active duty Marines currently fill a staffing goal billet and that 47% of all staffing goal billets are under-staffed.

EAM has several shortcomings; among these, the enlisted monitors reject most of its assignments and EAM offers no measure of effectiveness (MOE) to gauge the quality of its assignments.

EAM-GLOBAL provides an improvement.

EAM-GLOBAL test problems consist of up to 10,200 Marines, 16,100 billets, and 2.3 million candidate Marine-billet assignments. Using a personal computer with a 400-megahertz Pentium II processor and 16 Megabytes of random access memory and a primal simplex network solver, EAM-GLOBAL generates test problems within 15 minutes and solves each within 3 minutes. EAM-GLOBAL attempts to assign the "right Marines to the right places" while simultaneously evaluating balanced staffing shortages, grade and MOS substitutions, and costs of transcontinental permanent change of station transfers within the United States.

The billet SPL and unit deployment status was not made available in time for this thesis deadline. This lack of data made it unreasonable to invite the enlisted monitor critiques of EAM-GLOBAL assignments; such critiques would help adjust MBU values to produce better assignments.

B. CONTRIBUTIONS OF THESIS

This thesis highlights the lack of current manpower MOEs and introduces two staffing level MOEs and four assignment MOEs.

This thesis produces a prototype assignment model, EAM-GLOBAL. EAM-GLOBAL addresses the assignment problem in its entirety. That is, it allows for the possibility that some billets can be filled by a Marine of any MOS and thereby does not unnecessarily restrict potentially authorized assignments. EAM-GLOBAL produces executable assignments that adhere to USMC manpower policy.

C. RECOMMENDATIONS

USMC should adopt and use simple, unambiguous measures of effectiveness in manpower planning to gauge the achievement of policy goals. The USMC should use these MOEs to monitor staffing levels, quantify tradeoffs, and conduct "what-if" analysis.

USMC should implement a global model, such as EAM-GLOBAL.

USMC has been presented with three other decision support tools:

(1) Officer Mobilization Model [Bausch *et al.* 1991];

(2) Officer Staffing Goal Model [Sweeny 1993]; and

(3) Recruit Distribution Decision Support System [Snoap 1998].

Each of these addresses key issues that are still evidently problems for USMC manpower planning. Perhaps it is time for USMC to actually adopt and use tools such as these to address these problems.

LIST OF REFERENCES

Ahuja, Ravindra K., Magnanti, Thomas L., and Orlin, James B., Network Flows, Prentice-Hall, 1993.

Air Force Personnel Center, *Airman Assignments Handbook*, January 1993.

Ali, A., Kennington, J., and Liang, T., "Assignment with En Route Training of Navy Personnel," *Naval Research Logistics*, vol. 40, pp. 581-592, 1993.

Bausch, D.O., Brown, G.G., Hundley, D.R., Rapp, S.H., Rosenthal, R.E., "Mobilizing Marine Corps Officers," *Interfaces*, v. 21, pp.26-38, July-August 1991.

Bazaraa, M.S., Jarvis, J.J., Sherali, H.D., Linear Programming and Network Flows, Wiley, 1990.

Bradley, G.H., Brown, G.G., Graves, G.W., "Design and Implementation of Large Scale Primal Transshipment Algorithms," *Management Science,* v. 20, No. 1, pp. 1-34, September 1977.

Brooks, T.L., Col USAF, presentation, *Enlisted Assignments*, Chief, USAF Airman Assignments Division, June 1998.

Cunningham, T., personal communication with T. Cunningham, Liaison to Bureau of Naval Personnel, Navy Personnel Research and Development Center, September 11, 1998.

Decision Systems Associates, Inc., *U.S. Marine Corps PREPAS [Precise Personnel Assignment System] Model Conversion Software/Hardware Evaluation,* October 1992.

Defense Financing and Accounting Services, *Monthly Basic Pay,* http://www.dfas.mil/money//milplay/98pay/98bp.htm.

Deputy Chief of Staff for M&RA, *Manpower Process*, 1996.

EAM Turnover File, Systems Support Section (MMEA-5), M&RA, 1997.

Evers, C, Major, personal communication with C. Evers, Contracting Officer Technical Representative, Program for Manpower Information Systems, Marine Corps Systems Command, August 18, 1998.

Fourer, R., Gay, D.M., Kernighan, B.W., AMPL: A Modeling Language for Mathematical Programming, Duxbury Press 1993.

INSIGHT, INC., ENET (an elastic network solver), Manassas, VA, Copyright 1991, 1998.

Klingman, D., and Phillips, N., "Topological and Computational Aspects of Preemptive Multi-criteria military Personnel Assignment Problems," *Management Science*, vol. 30, no. 11, pp. 1362-1375, 1984.

Koch, G.D., *Re-Engineering The United States Marine Corps' Enlisted Assignment Model (EAM)*, Masters Thesis, Department of Systems Management, Naval Postgraduate School, Monterey, California, June 1998.

Lawphongpanich, T., personal communication with T. Lawphongpanich, former Deputy Chief of Staff for Personnel, USA, March 16, 1998.

Macfarlane, J., Captain, personal communication with J. Macfarlane, EAM Model Manager, Systems Support Section (MMEA-5), M&RA, November 1997.

Manes, F., Staff Sergeant, personal communication with F. Manes, Enlisted Infantry Monitor, Enlisted Monitor Section (MMEA-8), M&RA, November 1997.

Marines, "Major Marine Corps Installations," Division of Public Affairs, Media Branch, Head Quarters Marine Corps, February 1997.

Marren, L. Gunnery Sergeant, personal communication with L. Marren, Enlisted Military Police Monitor, Enlisted Monitor Section (MMEA-8),M&RA, November 1997.

Meckel, R.C., Lieutenant Colonel, personal communication with R.C. Meckel, former PCS Budget Planner, Operation Support Section for Personnel Management Division (MMOS), M&RA, September 18, 1998.

Microsoft Corporation, ACCESS (database), Redmond, WA, Copyright 1996.

Oracle Corporation, Oracle (database), Redwood Shores, CA, Copyright 1997.

Schank, J.F., Harrell, M.C., Thie, H.J., Pinto, M.M., Sollinger, J. M., Relating Resources to Personnel Readiness, RAND, 1997.

Snoap, K.J., *Reengineering the United States Marine Corps' Recruit Distribution Model (RDM)*, Masters Thesis, Department of Systems Management, Naval Postgraduate School, Monterey, California, September 1998.

Sweeny, J.B., *A Network Model (OSGM-NPS) For the U.S. Marine Corps Officer Staffing Goal Problem*, Masters Thesis, Department of Operations Research, Naval Postgraduate School, Monterey, California, September 1993.

USMC, Marine Corps Order P1300.8R, *Personnel Assignment Policy*.

INITIAL DISTRIBUTION LIST

1. Defense technical Information Center 2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library 2
   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, CA 93943-5101

3. Director, Training and Education 1
   MCCDC, Code C46
   1019 Elliot Road
   Quantico, VA 22134-5027

4. Director, Marine Corps Research Center 2
   MCCDC, Code C40RC
   2040 Broadway Street
   Quantico, VA 22134-5107

5. Director, Studies and Analysis Division 2
   MCCDC, Code C45
   3300 Russell Road
   Quantico, VA 22134-5130

6. Dr. Robert F. Dell, Code OR/De 2
   Department of Operations Research
   Naval Postgraduate School
   Monterey, CA 93943-5121

7. Dr. Hemant K. Bhargava, Code SM/BH 2
   Department of Systems Management
   Naval Postgraduate School
   Monterey, CA 93943

8. Headquarters, United States Marine Corps 2
   Attn: Capt Edward Dewald (MA)
   3280 Russell Rd.
   Quantico, VA 22134-5103

9. Marine Corps Representative 1
   Naval Postgraduate School
   Code 037, Bldg. 234, HA-220
   699 Dyer Road
   Monterey, CA 93940

10. Marine Corps Systems Command 3
Attn: Capt Brian F. Tivnan (PAE)
2033 Barnett Ave Suite 315
Quantico, VA 22134-5010

11. Marine Corps Tactical Systems Support Activity 1
Technical Advisory Branch
Attn: Maj J.C. Cummiskey
Box 555171
Camp Pendleton, CA 92055-5080